(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 May 2009 (14.05.2009)

PCT

(10) International Publication Number
WO 2009/062127 A3

(51) International Patent Classification:
H01M 8/02 (2006.01) *H01M 8/12* (2006.01)
H01M 8/04 (2006.01) *H01M 8/24* (2006.01)

(21) International Application Number:
PCT/US2008/082923

(22) International Filing Date:
8 November 2008 (08.11.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/986,368 8 November 2007 (08.11.2007) US
12/267,439 7 November 2008 (07.11.2008) US

(71) Applicants and
(72) Inventors: **DEVOE, Alan** [US/US]; 5715 Waverly Avenue, La Jolla, CA 92037 (US). **DEVOE, Lambert** [US/US]; 3446 Stadium Place, San Diego, CA 92122 (US).

(74) Agents: **DAVIDSON, Kristi, L.** et al.; Wood Herron & Evans, L.L.P., 441 Vine Street, 2700 Carew Tower, Cincinnati, OH 45202 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
9 July 2009

(54) Title: MULT I LAYERED SOFC DEVICE ON CERAMIC SUPPORT STRUCTURE

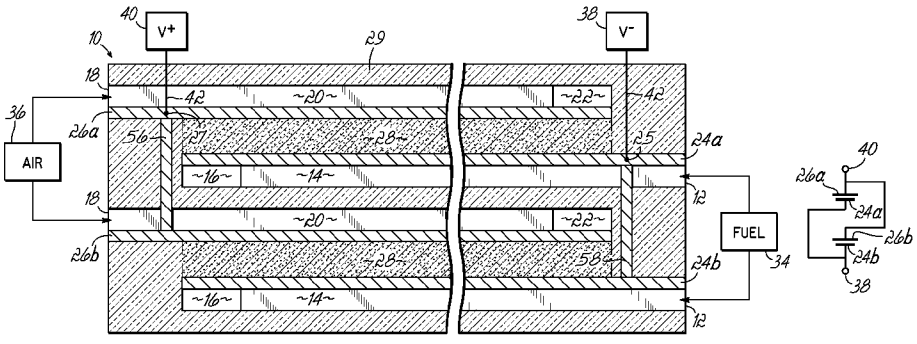


FIG. 8B

(57) Abstract: The fuel cell device (10) includes one or more active layers containing active cells (24a, 26a, 24b, 26b) that are connected electrically in parallel. The fuel cell device (10) includes an elongate ceramic support structure (29) the length of which is the greatest dimension such that the coefficient of thermal expansion has only one dominant axis coextensive with the length.

WO 2009/062127 A3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/082923

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/02 H01M8/04 H01M8/12 H01M8/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,L	US 2007/105003 A1 (DEVOE ALAN [US] ET AL) 10 May 2007 (2007-05-10) figures 9A,10	1-8
A	US 6 291 089 B1 (PIASCIK JAMES [US] ET AL) 18 September 2001 (2001-09-18) figure 1 column 4, lines 41-52	1-8

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 February 2009	28/05/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Jacquinot, Patrick

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/082923

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

see additional sheet(s)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8

fuel cell device comprising
a ceramic support structure having a first and second active layer in a heatable reaction zone
a first active cell in the first active layer comprising first anode, first cathode and a first electrolyte therebetween,
a second active cell in the second active layer comprising second anode, second cathode and a second electrolyte therebetween, and
the first and second active cells being electrically interconnected in parallel via distorted sections;
fuel cell system comprising such a fuel cell device

---

2. claims: 9-17

fuel cell device comprising
a ceramic support structure having at least a first active layer in a heatable reaction zone,
a first active cell in the first active layer comprising a first cathode and a first anode that includes a first porous anode portion in opposing relation to the first cathode and a first non-porous anode portion,
a second active cell in the first active layer adjacent the first active cell and comprising a second anode and a second cathode that includes a second porous cathode portion in opposing relation to the second anode and a second non-porous cathode portion,
a ceramic electrolyte in the first active layer between the first anode and the first cathode and between the second anode and the second cathode,
wherein the first non-porous anode portion is electrically connected to the second non-porous cathode portion within the ceramic support structure thereby connecting the first and second active cells in series in the first active layer;
fuel cell system comprising such a fuel cell device

---

3. claims: 18-32

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

fuel cell device comprising
a ceramic support structure having at least a first active layer in a heatable reaction zone,
a ceramic electrolyte layer in said first active layer,
a plurality of spaced apart first electrodes in the first active layer positioned on a first side of the ceramic electrolyte layer,
a plurality of spaced apart second electrodes in the first active layer positioned on a second side of the ceramic electrolyte layer,
a plurality of conductive elements extending between the plurality of spaced apart acitve cells wherein each of the plurality of conductive elements physically contacts the first electrode of one active cell, extends through the ceramic electrolyte layer in the space adjacent the one active cell, and physically contacts the second electrode of the adjacent spaced apart active cell thereby connecting the plurality of active cells in series in the first active layer;
fuel cell system comprising such a fuel cell device

---

4. claims: 33-36, 44

fuel cell device comprising
a ceramic support structure having a top and a bottom cover portion and having a heatable reaction zone,
a continuous active layer comprising a first electrode layer separated from a second electrode layer by a ceramic electrolyte layer and extending in zig-zag fashion from a first to a second end, the first end attached at or near the top cover portion and a second end attached at or near the bottom cover portion with an intermediate portion therebetween comprising active cell portions between first and second bend portions,
a first gas passage between active cell portions adjacent to the first electrode layer and a second gas passage between active cell portions adjacent to the second electrode layer,
wherein at least one of the first bends or the second bends are free from attachement to the ceramic support structure between the top and bottom cover portions;
fuel cell system comprising such a fuel cell device

---

5. claims: 37-43,45

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

a fuel cell device comprising
a ceramic support structure having at least one active layer therein and at least one elongate ceramic end tube having a cold end configured to be positioned outside a high-temperature reaction chamber and a hot end permanently attached to an end portion of the ceramic support structure, the at least one elongate ceramic end tube configured for supplying fuel and/or oxidant gas, and the at least one elongate ceramic end tube thermally expands only in the lengthwise direction,
wherein the at least one elongate ceramic end tube is permanently attached to the ceramic support structure by one or a combination of:
co-sintering both from a green state,
sintering the one to the other, wherein one is in a green state whereas the other is in a sintered state, or
applying a glass or glass ceramic adhesive between the sintered parts and sintering the adhesive;
fuel cell system comprising such a fuel cell device

---

6. claims: 46-53

a fuel cell device comprising an elongate ceramic flat tube having a width greater than height and having a plurality of fuel and oxidant channels extending in the elongate direction between first and second ends, the channels separated by internal ribs configured to prevent the mixing of fuel and oxidizer between channels,
a multilayer active structure attached to a flat surface of the elongate ceramic flat tube, the multilayer active structure comprising at least two active layers each comprising at least one active cell having anode, cathode and electrolyte, a fuel passage adjacent the anode and an oxidizer passage adjacent the cathode,
wherein the fuel (oxidizer) passage for each active cell is fluidly coupled to one or more of the plurality of fuel (oxidizer) channels of the elongate ceramic flat tube whereby fuel and oxidizer gas is configured to be fed into the respective fuel and oxidizer channels and then into the respective fuel and oxidizer passages.

---

7. claims: 54-57

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

a fuel cell device comprising
a multilayer active structure having a plurality of anode layers each containing a first plurality of microtubular and/or nanotubular passages therein stacked in alternating relation with a plurality of cathode layers each containing a second plurality of microtubular and/or nanotubular passages therein, and an electrolyte layer separating each anode layer from each alternating cathode layer, whereby the anode layers and cathode layers in an inside portion of the multilayer active cell structure each serve two adjacent electrolyte layers

---

8. claims: 58,59

a fuel cell device comprising
a ceramic support structure containing
a multilayer active cell structure having a plurality of anode layers, a plurality of cathode layers, an electrolyte layer separating each anode layer from each cathode layer, an active fuel passage integral with each anode layer and an active oxidizer passage integral with each cathode layer, the ceramic support structure further having first and second elongate members extending outwardly from one edge of the mulitlayer active cell structure, the first elongate member having a fuel supply passage coupled to the active fuel passages and the second elongate member having an oxidizer supply passage coupled to the active oxidizer passages;
fuel cell system comprising such a fuel cell device

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/082923

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007105003 A1	10-05-2007	NONE	
US 6291089 B1	18-09-2001	AT 263435 T	15-04-2004
		AU 766879 B2	23-10-2003
		AU 1436701 A	08-05-2001
		DE 60009542 D1	06-05-2004
		DE 60009542 T2	17-03-2005
		DK 1230706 T3	16-08-2004
		EP 1230706 A1	14-08-2002
		JP 2003513408 T	08-04-2003
		NO 20021954 A	25-06-2002
		WO 0131728 A1	03-05-2001